Reactions of thiobenzoylketene *S,N*-acetals with silyl enol ethers of cyclic ketones in the presence of desilylating reagents: formation and desulfurization of thienolactams

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Medium-sized thienolactams can be directly prepared from thiobenzoylketene *S,N*-acetals, $Hg(OAc)_2$, and silyl enol ethers of cyclic ketones, and either TBAF or TASF. However, by adding either water or alcohol to the foregoing mixture, 3-methylamino-5-phenylthiophenes, in which the ω-position of long-chain alkanoic acids and alkanoic esters are bonded to C-2 of the thiophene ring, can be obtained albeit in low yields. Sequential treatment of the thienolactams with Raney nickel and Adam's catalyst results in completely reductive desulfurization of thienolactam molecules.

Introduction

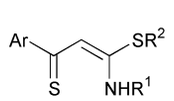
Owing to the importance of lactams as starting materials for the preparation of a large range of antibacterial agents, methods of synthesis and interconversion of the functional group are of great significance to a large number of practicing organic chemists. Information about the synthesis of lactams may be found in numerous review articles.[1] However, there are few known examples of methods for introducing a substituent α to the ring nitrogen of lactams larger than a seven-membered ring. That is, intramolecular cyclization of amino esters provides medium-sized lactams.[2] The Beckmann rearrangement is used in the preparation of the desired lactams.[3] The Schmidt reaction has been widely employed for the preparation of lactams from cyclic ketones.[4] Ultraviolet and ultraviolet–visible irradiation of a large variety of substituted amides would give lactams.[5] Sodium peroxide oxidation of substituted benzothiazepinones and benzoxazepinones has produced the corresponding nine-membered benzothiazonediones and benzoxazonediones.[6] Medium-sized keto lactams were synthesized by a three-atom condensative ring expansion of the related fused tricyclic oxaziridines.[7]

Recently we reported a new, versatile synthetic method for 2-substituted 3-alkylamino-5-arylthiophenes by treatment of thioaroylketene *S,N*-acetals **1** with enolizable compounds in the presence of $Hg(OAc)_2$ in CH_2Cl_2 at rt.[8] We tried to extend this methodology to monocyclic ketones in order to obtain ω-(2-thienyl)alkanoic acids **2** in a single step since compound **2**-bearing chains longer than four carbon units have been achieved by the acylation of thiophene using ω-chloroalkanoyl chlorides in the presence of Lewis acid, followed by an appropriate transformation of the functional group(s).[9] We have studied this possibility by employing cyclohexanone, decanone, dodecanone, and 5α-cholestan-3-one. We now report the results of our study of these reactions.

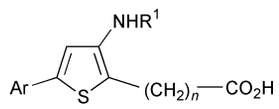
Results and discussion

(A) In the presence of desilylating reagents

Treatment of **1a** (Ar = Ph, $R^1 = R^2 = Me$) with $Hg(OAc)_2$ in CH_2Cl_2, followed by addition of cyclohexanone gave, however, 2-methyl-5-phenylisothiazol-3-one **3** as a major product (64%). It is known that compound **3** is formed in the absence of an active nucleophile.[8]



1a Ar = Ph
$R^1 = R^2 = Me$



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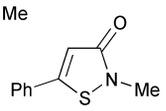

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Since cyclohexanone did not participate as a nucleophile, the reaction with the trimethylsilyl enol ether of cyclohexanone was carried out. However, compound **3** was again isolated as a major product along with unknown mixtures. This result suggests that the silyl enol ether does not act as a nucleophile by itself without assistance from an activating agent. Therefore, tris(dimethylamino)(trimethylsilyl)sulfur difluoride (TASF), which is known to be a good desilylating reagent,[10] was added to a stirred mixture of **1a**, $Hg(OAc)_2$, and the trimethylsilyl enol ether of cyclohexanone. The mixture was stirred until no spot corresponding to **1a**–mercury complex was observed on TLC. Unexpectedly the reaction mixture gave thienolactam **4a** ($n = 4$) in 30% yield (Scheme 1). Similarly, the reactions with the trimethylsilyl enol ethers of decanone and dodecanone under the same reaction conditions yielded the corresponding thienolactams **4b**,**c**. To test this methodology for polycyclic ketones, a mixture of regioisomers **5** and **6**, prepared by the reaction of 5α-cholestan-3-one with TMSCl[11] whose ratio was determined to be 74 : 26 based on the intensities of the vinyl protons appearing at δ 4.76 and 4.48, respectively, was subjected to the same conditions (Scheme 2). Interestingly, only a single thienolactam, assigned to be **4d**, was isolated in 46% yield along with unknown mixtures. The absence of a product originating from **6** may be due to a severe steric hindrance arising from the interaction between **1a**–mercury complex and **6** to form the corresponding dihydrothiophene intermediate.[8] Reaction times, yields, and mps are summarized in Table 1.

As an alternative desilylating agent, tetrabutylammonium fluoride (TBAF)[12] was tried but it turned out to be inferior to TASF except for the reaction with the dodecanone derivative (entry 3). On the other hand, treatment with benzyltrimethyl-

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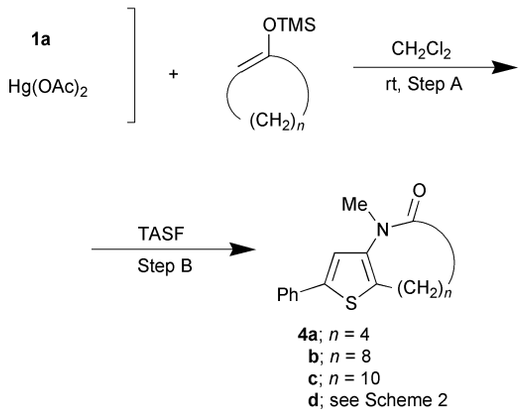
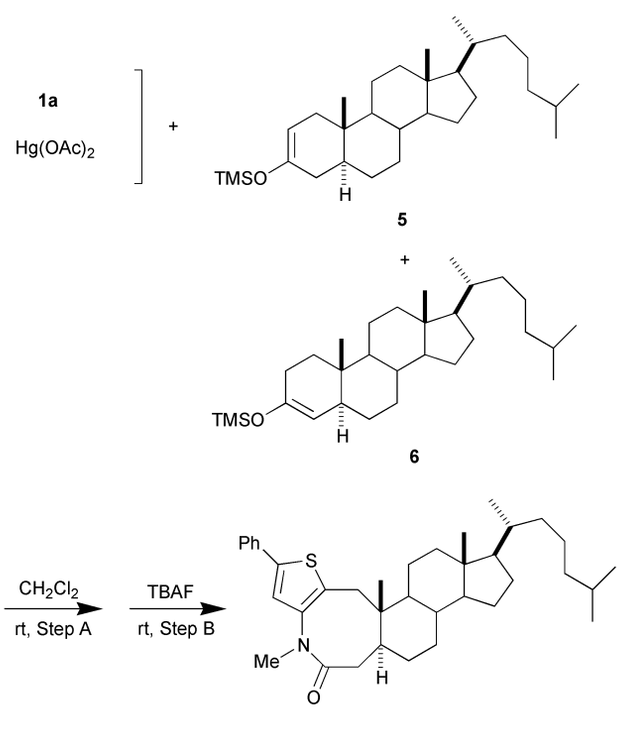
Table 1 Reaction times, yields, and mps of thienolactams **4**

Entry	Trimethylsilyl enol ether of	Time (*t*/min) Step A	Time (*t*/h) Step B	Compd	Yield[a] (%) TASF	Yield[a] (%) TBAF	Mp (*T*/°C)
1	Cyclohexanone	5	48	**4a** (*n* = 4)	30	28[b]	Liquid
2	Decanone	5	4	**4b** (*n* = 8)	44	31	150–151[c]
3	Dodecanone	5	5	**4c** (*n* = 10)	16	33	Liquid
4	5α-Cholestan-3-one	5	72	**4d**	46	25	201–203[c]

[a] Isolated yields. [b] 5-(3-Methylamino-5-phenylthien-2-yl)pentanoic acid **9a** (*n* = 4, R = H) (5%) was isolated. [c] Recrystallized from a mixture of Et_2O and *n*-hexane.



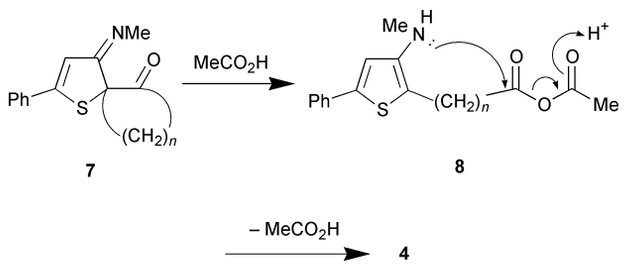
Scheme 1



Scheme 2

ammonium fluoride hydrate (BTAF)[13] gave **4a** and **4b** in 23 and 16% yield, respectively. Addition of BTAF, followed by use of molecular sieves (4 Å) in order to remove the hydrate water, was not useful. Unchanged **1** (28%) was recovered along with an unknown mixture. The results suggest that BTAF is not effective for the preparation of compounds **4**. Yields obtained when TBAF was used are summarized in Table 1.

The formation of medium-size lactams **4a**–**d** suggests that the corresponding intermediate **7**, proposed for the formation of thiophene derivatives from **1**, $Hg(OAc)_2$, and enolizable ketones,[8] is attacked by a new nucleophile in the solvent to give a reactive intermediate (Scheme 3). Intramolecular nucleophilic



Scheme 3

attack by the methylamino group at C-3 of the thiophene ring on the nucleophilic center of the reactive intermediate should give **4**. One can envisage acetic acid generated from $Hg(OAc)_2$ as a possible nucleophile. Acetolysis of **7** would give an anhydride **8**, which undergoes intramolecular cyclization to give **4**.

(B) Trapping of intermediate 7 with hydroxy nucleophiles

Since lactams **4** were envisaged to be formed *via* a nucleophilic attack of acetic acid on the intermediate **7** during a prolonged reaction time, the stirring time, following the addition of desilylating reagent, was reduced to 1 h, and then hydroxy nucleophiles, *i.e.*, EtOH, MeOH, and water, were added to trap the intermediate **7** (Scheme 4). From the reaction mixture we isolated ω-(2-thieno)alkanoic acids or their esters, depending on the hydroxy nucleophiles. The results are summarized in Table 2.

Although yields of compound **9** and **10** are not satisfactory, one can directly obtain ω-(2-thieno)alkanoic acids and their esters by this methodology. When the intermediate **7** (*n* = 4) was quenched with phenylmethanethiol, thioester **11** (42%) was obtained as a major product, whereas quenching with *n*-propylamine resulted only in **9a** (29%), presumably due to the involvement of moisture in wet *n*-propylamine. Similar treatment with morpholine in toluene for 10 h at reflux afforded thienolactam **4a** (*n* = 4) (25%) and **9a** (6%) in addition to a trace amount of amide **12** whose structure was assigned based on its mass number, *m*/*z* = 385, equal to its relative molecular mass. Therefore the intermediate **7** may be unsuitable for the preparation of thiophenes having an alkanamide moiety at C-2.

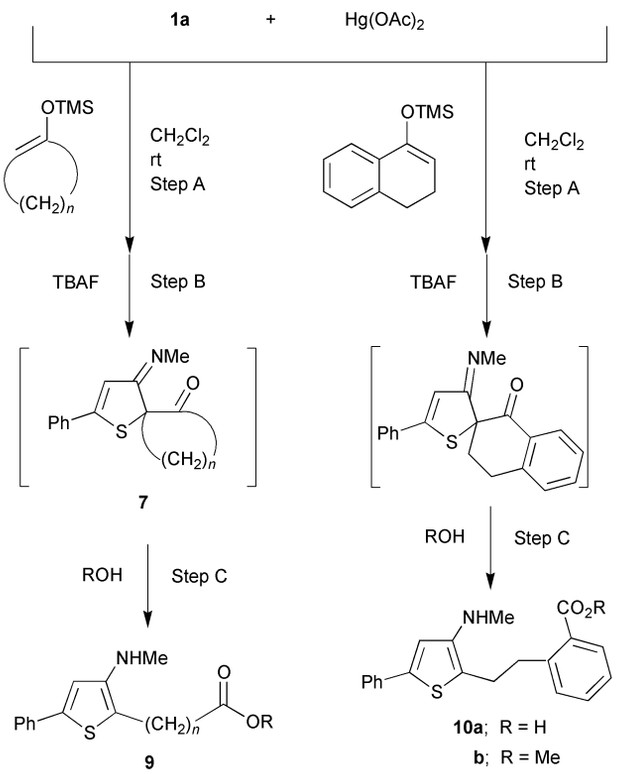
(C) Reductive desulfurization

Destruction of the thiophene ring by Raney nickel is known to be one of the major methods for increasing carbon chains by four carbon units, from which the thiophene derivatives are transformed into a plethora of open-chain products not easily accessible by other routes.[14] In fact, oximation of 6,7-dihydrobenzo[*b*]thiophen-4(5*H*)-ones, followed by Beckmann rearrangement, gave C-substituted ξ-thienolactams which underwent desulfurization by Raney nickel to give the

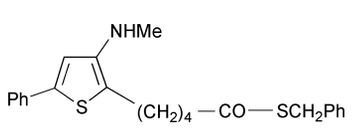
Table 2 Synthesis of ω-(2-thieno)alkanoic acids **9a**, **9e**,**f**, and **10a** and ω-(2-thieno)alkanoic esters **9b–d**, **9g**, and **10b**

Entry	Trimethylsilyl enol ether of ketone	Time (*t*/min) Step A [a]	Time (*t*/h) Step B [b]	Time (*t*/h) Step C [c]	Temp.	R	Compd	Yield [d] (%)
1	Cyclohexanone	5	1	1	rt	H	**9a** (*n* = 4)	34
2	Cyclohexanone	5	1	3	Reflux	Et	**9b** (*n* = 4)	44
3	Cycloheptanone	3	1	3	rt	Et	**9c** (*n* = 5)	39
4	Cyclooctanone	3	1	3	rt	Et	**9d** (*n* = 6)	36
5	Cyclododecanone	5	1	5	rt	H	**9e** (*n* = 10)	26
6	Cyclopentadecanone	5	2	4	rt	H	**9f** (*n* = 13)	31
7	Cyclopentadecanone	10	3	0.5	Reflux	Me	**9g** (*n* = 13)	32
8	1-Tetralone	10	4	0.5	rt	H	**10a**	46
9	1-Tetralone	10	4	0.5	rt	Me	**10b**	56

[a] Stirring time after silyl enol ether was added to the mixture of **2a** and $Hg(OAc)_2$. [b] Stirring time after TBAF was added. [c] Stirring time after nucleophile was added. [d] Isolated yields.



Scheme 4



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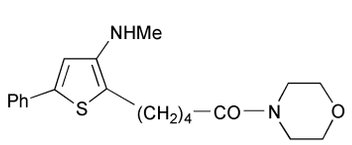

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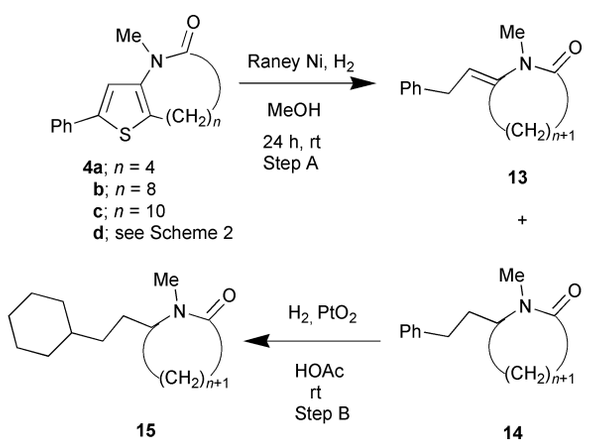
corresponding ξ-alkyl-ξ-enantholactams. This methodology for ξ-enantholactams and ε-caprolactams was extensively studied by Shalavina and co-workers.[15] However, no-larger than eight-membered lactams have been reported by this method.[14c] Similar treatment of compound **4a** (*n* = 4) with Raney nickel in MeOH for 24 h, however, gave 1-methyl-8-(2-phenylethylidene)azocin-2-one **13a** (*n* = 4) and 1-methyl-8-(2-phenylethyl)-azocin-2-one **14a** (*n* = 4) in 23 and 42% yield, respectively (Scheme 5). Compounds **13a** and **14a** were separated by chromatography.



Scheme 5

The structures of compounds **13a** and **14a** were determined based on spectroscopic and analytical data. In particular, 2D NMR techniques are informative regarding the position of the olefinic double bond of compound **13a**. Since compound **4a** was incompletely reduced by Raney Ni to give a mixture of compounds **13a** and **14a**, the mixture was isolated by chromatography and subsequent treatment of the mixture with a catalytic amount of PtO_2 (3 wt%) in HOAc[15] gave the 8-(2-cyclohexylethyl)heptanolactam (**15a**, *n* = 4) (58%). Similar treatment of compounds **4b–d** with Raney nickel and PtO_2 in sequence under the same conditions gave compounds **15b–d** in moderate to good yields. To the best of our knowledge, this is the first example of the synthesis of larger-than eight-membered lactams bearing a 2-cyclohexylethyl group at the carbon α to the ring nitrogen. Direct treatment of **4a** with PtO_2 for 72 h under the same conditions did not give reduced products, with almost quantitative recovery of starting lactam. Reaction times, and yields of lactams **15** are summarized in Table 3.

Apart from the ^{1}H NMR spectroscopic data for **15a**, the ^{1}H NMR spectra of compounds **15b**, **15c** and **15d** show that each compound consists of two isomers, presumably conformational isomers in view of reports[14f] showing undecanolactam is present only as a *trans* isomer having two different ring conformations. The ratio of the isomers of compound **15b** were determined to be 1.43 : 1, based on the intensities of N-CH_3 (δ 2.72, 2.79) and methine (δ 3.74–3.76, 4.71–4.75) proton

Table 3 Reaction times and yields of lactams **15**

	Thienolactam	Time (*t*/day) Step A	Step B	Compd	Yield[a] (%)
4a	(*n* = 4)	1	1	**15a**	58
4b	(*n* = 8)	1	1	**15b**	66
4c	(*n* = 10)	1	1	**15c**	43
4d		1	4	**15d**	81

[a] Isolated yields.

signals. Similarly, that of compound **15c** was 1.16 : 1, which was determined based on those of N-CH_3 (δ 2.76, 2.70) and methine (δ 4.66–4.73, 3.71–3.77) proton signals. That of compound **15d** was 2.36 : 1, which was determined based on those of N-CH_3 (δ 2.95, 2.96) and methine (δ 5.21–5.25, 4.90–4.91) proton signals. However, more information is needed to clearly assign the spectral data of compounds **15b**–**d**.

Experimental

The ^{1}H NMR spectra were recorded at 300, 500, or 600 MHz in $CDCl_3$ solution containing tetramethylsilane as internal standard: *J*-values are given in Hz. IR spectra were recorded in KBr or thin-film samples on KBr plates. Mass spectra were obtained by electron impact at 70 eV. Elemental analyses were determined by the National Center for Inter-University Research Facilities, Seoul National University. Column chromatography was performed using silica gel (Merck, 230–400 mesh ASTM), unless otherwise stated. Mps were determined on a Fisher-Johns melting-point apparatus and are uncorrected. Dichloromethane was pre-dried over calcium hydride. 1-Methylamino-1-methylsulfanyl-3-phenyl-3-thioxopropene **1a** was prepared according to the documented procedure.[8]

General procedure for the synthesis of thienolactams 4a–d

(i) In the presence of tris(dimethylamino)(trimethylsilyl)-sulfur difluoride (TASF). To a mixture of compound **1a** (0.224–0.448 mmol) and $Hg(OAc)_2$ (0.314–0.627 mmol) in CH_2Cl_2 (8–10 cm^3) at rt was added the trimethylsilyl enol ether of a cyclic ketone (0.296–0.672 mmol). The mixture was stirred for 5 min under argon atmosphere, followed by addition of TASF (0.269–0.672 mmol). The mixture was stirred for an additional time (refer to Table 1) until no spot corresponding to the complex formed from **1a** and $Hg(OAc)_2$ was observed on TLC (R_f = 0, *n*-hexane–EtOAc 4 : 1). After the solid formed was filtered off, the filtrate was sequentially washed with 20% aq. $NaHCO_3$ and brine, and dried over $MgSO_4$. After removal of the solvent *in vacuo*, the residue was chromatographed on a silica gel (1 × 30 cm) using a mixture of EtOAc and *n*-hexane (2 : 1) to give a compound **4a**–**d**.

4-Methyl-2-phenyl-6,7,8,9-tetrahydrothieno[3,2-b]azocin-5(4H)-one ***4a***. In accordance with the above general procedure, the residue obtained from a stirred solution of a mixture of compound **1a** (50 mg, 0.224 mmol), $Hg(OAc)_2$ (100 mg, 0.314 mmol), (cyclohexen-1-yloxy)trimethylsilane (46 mg, 0.269 mmol), and TASF (74 mg, 0.269 mmol) was chromatographed to give title compound **4a** (18 mg, 30%) as a colorless liquid (Found: C, 70.7; H, 6.3; N, 5.2; S, 11.85. $C_{16}H_{17}NOS$ requires C, 70.8; H, 6.3; N, 5.2; S,11.8%); ν_{max} (neat)/cm^{-1} 2920, 1656, 1558, 1437, 1364, 1078 and 757; δ_H (600 MHz; $CDCl_3$) 1.38 (1 H, ddd, *J* 25.9, 13.0, 4.3, H-8), 1.69–1.82 (1 H, m, H-7), 1.97–2.06 (2 H, m, H-7 and H-8), 2.20 (1 H, t, *J* 12.2, $COCH_2$), 2.42–2.45 (1 H, m, $COCH_2$), 2.45–2.51 (1 H, m, H-9), 2.95 (1 H, dd, *J* 14.8, 6.8, H-9), 3.29 (3 H, s, NCH_3), 7.06 (1 H, s, thienyl), 7.29–7.31 (1 H, m, ArH), 7.37–7.40 (2 H, m, ArH) and 7.53–7.74 (2 H, m, ArH); δ_c (75 MHz; $CDCl_3$) 25.6 (C-7), 26.2 (C-9), 28.6 (C-8), 33.5 (C-6), 35.7 (NCH_3), 119.2 (C-3), 125.2, 127.8, 129.0, 133.7 (C-2), 135.9 (C-9a), 139.2 (C-3a), 140.4 and 174.7 (C=O).

4-Methyl-2-phenyl-6,7,8,9,10,11,12,13-octahydrothieno[3,2-b]azacyclododecan-5(4H)-one ***4b***. In accordance with the above general procedure, the residue obtained from a stirred solution of a mixture of compound **1a** (50 mg, 0.224 mmol), $Hg(OAc)_2$ (100 mg, 0.314 mmol), (cyclodecen-1-yloxy)trimethylsilane (61 mg, 0.269 mmol), and TASF (74 mg, 0.269 mmol) was chromatographed to give title compound **4b** (32 mg, 44%), mp 150–151 °C (from Et_2O–*n*-hexane) (Found: C, 73.6; H, 7.7; N, 4.3; S, 9.8. $C_{20}H_{25}NOS$ requires C, 73.35; H, 7.7; N, 4.3; S, 9.8%); ν_{max} (neat)/cm^{-1} 2928, 1657, 1440, 1386 and 756; δ_H (600 MHz; $CDCl_3$) 0.93–0.96 (1 H, m), 1.13–1.15 (1 H, m), 1.25–1.28 (2 H, m), 1.31–1.41 (3 H, m), 1.42–1.51 (2 H, m), 1.75–1.86 (2 H, m), 1.97–2.03 (1 H, m), 2.11–2.16 (1 H, m, $COCH_2$), 2.35 (1 H, ddd, *J* 16.2, 10.5, 3.4, $COCH_2$), 2.73 (1 H, dt, *J* 15.1, 4.4, H-13), 2.88–2.93 (1 H, ddd, *J* 15.4, 12.0, 4.3, H-13), 3.22 (3 H, s, NCH_3), 6.94 (1 H, s, thienyl), 7.28–7.30 (1 H, m, ArH), 7.36–7.39 (2 H, m, ArH) and 7.54–7.56 (2 H, m, ArH); δ_c (75 MHz; $CDCl_3$) 24.4, 24.5, 25.3, 25.8, 26.7, 27.4, 29.4, 32.1 (C-6), 36.4 (NCH_3), 122.0 (C-3), 125.1, 127.8, 128.9, 133.7 (C-2), 139.2 (C-13a), 139.5 (C-3a), 140.6 and 174.3 (C=O).

4-Methyl-2-phenyl-6,7,8,9,10,11,12,13,14,15-decahydrothieno-[3,2-b]azacyclotetradecan-5(4H)-one ***4c***. In accordance with the above general procedure, the residue obtained from a stirred solution of a mixture of compound **1a** (50 mg, 0.224 mmol), $Hg(OAc)_2$ (100 mg, 0.314 mmol), (cyclododec-1-enyloxy)-trimethylsilane (68 mg, 0.269 mmol), and TASF (74 mg, 0.269 mmol) was chromatographed to give title compound **4c** (13 mg, 16%) as a colorless liquid (Found: C, 74.4; H, 8.3; N, 4.0; S, 9.0. $C_{22}H_{29}NOS$ requires C, 74.3; H, 8.2; N, 3.9; S, 9.0%); ν_{max} (neat)/cm^{-1} 2928, 1656, 1435, 1387 and 755; δ_H (600 MHz; $CDCl_3$) 1.21–1.25 (6 H, m), 1.27–1.36 (3 H, m), 1.37–1.42 (4 H, m), 1.49–1.55 (1 H, m), 1.71–1.79 (1 H, m), 1.82–1.89 (1 H, m), 2.10 (1 H, dt, *J* 15.7, 6.5, $COCH_2$), 2.28–2.34 (1 H, m, $COCH_2$), 2.67 (1 H, dt, *J* 15.3, 6.9, H-15), 2.79-2.84 (1 H, m, H-15), 3.20 (3 H, s, NCH_3), 7.01 (1 H, s, thienyl), 7.28–7.30 (1 H, m, ArH), 7.37–7.39 (2 H, m, ArH) and 7.51–7.55 (2 H, m, ArH).

Thienolactam ***4d***. In accordance with the above general procedure, the residue obtained from a stirred solution of a mixture of compound **1a** (100 mg, 0.448 mmol), $Hg(OAc)_2$ (200 mg, 0.627 mmol), [5α-cholest-2(3)-en-3-yloxy]trimethylsilane (4.11 mg, 0.895 mmol), which is a mixture of regioisomers **5** and **6**, and TASF (185 mg, 0.672 mmol) was chromatographed to give title compound **4d** (115 mg, 46%) as a white solid, mp 201–203 °C (from Et_2O–*n*-hexane); ν_{max} (neat)/cm^{-1} 2935, 1654, 1458, 752 and 726; δ_H (600 MHz; $CDCl_3$) 0.69 (3 H, s, CH_3), 0.77 (3 H, s, CH_3), 0.86 (3 H, d, *J* 2.9, CH_3), 0.87 (3 H, d, *J* 2.9, CH_3), 0.91 (3 H, d, *J* 6.5, CH_3), 1.01–1.04 (5 H, m), 1.09–1.14 (7 H, m), 1.50–1.55 (1 H, m), 1.57–1.62 (2 H, m), 1.62–1.66 (2 H, m), 1.69–1.74 (1 H, m), 1.79–1.85 (2 H, m), 2.02–2.05 (1 H, m, $COCH_2$), 2.23 (1 H, d, *J* 14.7, $COCH_2$), 2.56 (1 H, dd, *J* 15.2, 10.4, H-9), 3.09 (1 H, d, *J* 14.7, H-9), 3.29 (3 H, s, NCH_3), 7.07 (1 H, s, thienyl), 7.28–7.30 (1 H, m, ArH), 7.37–7.39 (2 H, m, ArH) and 7.54–7.57 (2 H, m, ArH); δ_c (75 MHz; $CDCl_3$) 12.2, 13.1, 18.6, 22.2, 22.6, 22.8, 23.8, 24.2, 28.0, 28.3, 32.0, 32.7, 35.5, 35.7, 35.8, 36.1, 36.9, 37.6, 37.8, 39.5, 40.1, 42.4, 48.6, 52.3, 56.1, 56.7, 118.7 (C-3), 125.2, 127.8, 129.0, 131.8 (C-2), 133.7 (C-9a), 140.2 (C-3a), 140.6 and 174.6 (C=O); *m*/*z* HRMS (FAB) Calc. for $C_{37}H_{53}NOS$: [*M* + H]; 560.3926. Found: *m*/*z*, 560.3932.

(ii) In the presence of tetrabutylammonium fluoride (TBAF). The reactions were carried out according to the general procedure described in (i) except for using TBAF in place of TASF. Exactly the same amounts of reactants for each reaction were used. Yields of **4a**–**d** are listed in Table 1.

(iii) In the presence of benzyltrimethylammonium fluoride hydrate (BTAF). (*A*) The reaction was carried out using BTAF (55 mg, 0.320 mmol) in place of TASF according to the procedure described in (i). Exactly the same amounts of reactants for each reaction were used. Compounds **4a** (16 mg, 26%) and **4b** (20 mg, 27%) were obtained.

(*B*) The reaction was carried out in the presence of BTAF (55 mg, 0.320 mmol) and molecular sieves (4 Å) (500 mg) according to the procedure described in (i). However, compound **1a** (14 mg, 28% recovery) along with unknown mixtures were obtained.

General procedure for the synthesis of ω-(2-thieno)alkanoic acids 9a, 9e,f and 10a and their esters 9b–d, 9g and 10b

To a mixture of **1a** (0.224 mmol) and $Hg(OAc)_2$ (0.314–0.317 mmol) in CH_2Cl_2 (8 cm^3) at rt was added the trimethylsilyl enol ether of a cyclic ketone (0.260–0.288 mmol). The mixture was stirred for an appropriate time (3–10 min), followed by addition of TBAF (0.245–0.275 mmol), which was stirred for an additional time (1–3 h). Subsequent addition of water (5 cm^3) or alcohol (5 cm^3) gave a mixture, which was stirred for an additional time (0.5–5 h) and worked up as described in (i) of the general procedure for the synthesis of compounds **4**. The residue was chromatographed (1.5 × 15 cm) using a mixture of EtOAc and *n*-hexane (1 : 4) to give compounds **9** and **10**. Consult Table 2 for the reaction time and temperature.

5-[2-(3-Methylamino-5-phenyl)thieno]pentanoic acid 9a. In accordance with the above general procedure, the residue obtained from a stirred solution of a mixture of compound **1a** (50 mg, 0.224 mmol), $Hg(OAc)_2$ (101 mg, 0.317 mmol), (cyclohexen-1-yloxy)trimethylsilane (49 mg, 0.288 mmol) and TBAF (72 mg, 0.275 mmol) was chromatographed to give title compound **9a** (22 mg, 34%) as a pale yellow liquid (Found: C, 66.4; H, 6.6; N, 4.9; S, 11.0. $C_{16}H_{19}NO_2S$ requires C, 66.4; H, 6.6; N, 4.8; S, 11.1%); ν_{max} (neat)/cm^{-1} 2928, 1706 and 1568; δ_H (300 MHz; $CDCl_3$) 1.67–1.74 (4 H, m, 2 × CH_2), 2.40 (2 H, t, *J* 7.1, CH_2CO_2H), 2.62 [2 H, t, *J* 7.1, $CH_2(CH_2)_3CO_2H$], 2.91 (3 H, s, NCH_3), 6.96 (1 H, s, thienyl), 7.21–7.24 (1 H, m, ArH), 7.30–7.35 (2 H, m, ArH) and 7.52–7.55 (2 H, m, ArH).

Ethyl 5-[2-(3-methylamino-5-phenyl)thieno]pentanoate 9b. In accordance with the above general procedure, the residue obtained from a stirred solution of a mixture of compound **1a** (50 mg, 0.225 mmol), $Hg(OAc)_2$ (100 mg, 0.314 mmol), (cyclohexen-1-yloxy)trimethylsilane (46 mg, 0.270 mmol) and TBAF (71 mg, 0.271 mmol) and EtOH (5 cm^3) was chromatographed to give title compound **9b** (30 mg, 44%) as a yellow liquid (Found: C, 68.2; H, 7.3; N, 4.4; S, 10.0. $C_{18}H_{23}NO_2S$ requires C, 68.1; H, 7.3; N, 4.4; S, 10.1%); ν_{max} (neat)/cm^{-1} 3384, 2928, 1726, 1568, 1388, 1178 and 755; δ_H (300 MHz; $CDCl_3$) 1.25 (3 H, t, *J* 7.1, CH_2CH_3), 1.67–1.74 (4 H, m, 2 × CH_2), 2.34 (2 H, t, *J* 7.1, $CH_2CH_2CO_2$), 2.60 [2 H, t, *J* 7.1, $CH_2(CH_2)_3CO$], 2.91 (3 H, s, NCH_3), 3.02 (1 H, br, s, NH), 4.12 (2 H, q, *J* 7.1, CH_2CH_3), 6.95 (1 H, s, thienyl), 7.21–7.24 (1 H, m, ArH), 7.0–7.35 (2 H, m, ArH) and 7.52–7.55 (2 H, m, ArH).

Ethyl 6-[2-(3-methylamino-5-phenyl)thieno]hexanoate 9c. In accordance with the above general procedure, the residue obtained from a stirred solution of a mixture of compound **1a** (52 mg, 0.234 mmol), $Hg(OAc)_2$ (100 mg, 0.314 mmol), (cyclohepten-1-yloxy)trimethylsilane (46 mg, 0.250 mmol) and TBAF (67 mg, 0.256 mmol) and EtOH (3 cm^3) was chromatographed to give title compound **9c** (30 mg, 39%) as a yellow liquid (Found: C, 68.8; H, 7.6; N, 4.3; S, 9.65. $C_{19}H_{25}NO_2S$ requires C, 68.85; H, 7.6; N, 4.2; S, 9.7%); ν_{max} (neat)/cm^{-1} 3384, 2929, 1725, 1568, 1388, 1178 and 755; δ_H (300 MHz; $CDCl_3$) 1.25 (3 H, t, *J* 7.1, CH_3), 1.42–1.45 (2 H, m, CH_2), 1.62–1.66 (4 H, m, 2 × CH_2), 2.30 (2 H, t, *J* 7.1, $CH_2CH_2CO_2$), 2.58 [2 H, t, *J* 7.1, $CH_2(CH_2)_4$], 2.91 (3 H, s, NCH_3), 4.12 (2 H, q, *J* 7.1, CH_2CH_3), 6.95 (1 H, s, thienyl), 7.21–7.24 (1 H, m, ArH), 7.30–7.35 (2 H, m, ArH) and 7.52–7.55 (2 H, m, ArH).

Ethyl 7-[2-(3-methylamino-5-phenyl)thieno]heptanoate 9d. In accordance with the above general procedure, the residue obtained from a stirred solution of a mixture of compound **1a** (48 mg, 0.216 mmol), $Hg(OAc)_2$ (99 mg, 0.311 mmol), (cycloocten-1-yloxy)trimethylsilane (50 mg, 0.252 mmol) and TBAF (70 mg, 0.268 mmol) and EtOH (3 cm^3) was chromatographed to give title compound **9d** (27 mg, 36%) as a yellow liquid (Found: C, 69.50; H, 7.9; N, 4.1; S, 9.2. $C_{20}H_{27}NO_2S$ requires C, 69.5; H, 7.9; N, 4.05; S, 9.3%); ν_{max} (neat)/cm^{-1} 3384, 2929, 1725, 1568, 1388, 1178 and 755; δ_H (300 MHz; $CDCl_3$) 1.25 (3 H, t, *J* 7.1, CH_3), 1.38–1.42 (4 H, m, 2 × CH_2), 1.62–1.66 (4 H, m, 2 × CH_2), 2.30 (2 H, t, *J* 7.1, $CH_2CH_2CO_2$), 2.58 [2 H, t, *J* 7.1, $CH_2(CH_2)_5$], 2.92 (3 H, s, NCH_3), 4.13 (2 H, q, *J* 7.1, CH_2CH_3), 6.95 (1 H, s, thienyl), 7.21–7.24 (1 H, m, ArH), 7.30–7.35 (2 H, m, ArH) and 7.52–7.55 (2 H, m, ArH).

11-[2-(3-Methylamino-5-phenyl)thieno]undecanoic acid 9e. In accordance with the above general procedure, the residue obtained from a stirred solution of a mixture of compound **1a** (50 mg, 0.224 mmol), $Hg(OAc)_2$ (100 mg, 0.314 mmol), (cyclododec-1-enyloxy)trimethylsilane (68 mg, 0.267 mmol) and TBAF (59 mg, 0.226 mmol) and water (1 cm^3) was chromatographed to give title compound **9e** (22 mg, 26%) as a yellow liquid (Found: C, 70.8; H, 8.4; N, 3.7; S, 8.5. $C_{22}H_{31}NO_2S$ requires C, 70.7; H, 8.4; N, 3.75; S, 8.6%); ν_{max} (neat)/cm^{-1} 2920, 1700, 1586, 1453 and 755; δ_H (300 MHz; $CDCl_3$) 1.24–1.37 (12 H, m, 6 × CH_2), 1.61–1.65 (4 H, m, 2 × CH_2), 2.35 (2 H, t, *J* 7.5, $CH_2CH_2CO_2$), 2.59 [2 H, t, *J* 7.5, $CH_2(CH_2)_9$], 2.92 (3 H, s, NCH_3), 6.97 (1 H, s, thienyl), 7.21–7.26 (1 H, m, ArH), 7.30–7.36 (2 H, m, ArH) and 7.53–7.56 (2 H, m, ArH).

14-[2-(3-Methylamino-5-phenyl)thieno]tetradecanoic acid 9f. In accordance with the above general procedure, the residue obtained from a stirred solution of a mixture of compound **1a** (50 mg, 0.224 mmol), $Hg(OAc)_2$ (100 mg, 0.314 mmol), (cyclopentadec-1-enyloxy)trimethylsilane (77 mg, 0.260 mmol) and TBAF (64 mg, 0.245 mmol) and water (1 cm^3) was chromatographed to give title compound **9f** (29 mg, 31%) as a yellow liquid (Found: C, 72.2; H, 9.0; N, 3.3; S, 7.8. $C_{25}H_{37}NO_2S$ requires C, 72.2; H, 9.0; N, 3.4; S, 7.7%); ν_{max} (neat)/cm^{-1} 2920, 1698, 1585, 1453 and 755; δ_H (300 MHz; $CDCl_3$) 1.23–1.38 (18 H, m, 9 × CH_2), 1.62–1.66 (4 H, m, 2 × CH_2), 2.33 (2 H, t, *J* 7.5, $CH_2CH_2CO_2$), 2.58 [2 H, t, *J* 7.5, $CH_2(CH_2)_{12}$], 2.92 (3 H, s, NCH_3), 6.97 (1 H, s, thienyl), 7.21–7.26 (1 H, m, ArH), 7.30–7.36 (2 H, m, ArH) and 7.53–7.56 (2 H, m, ArH).

Methyl 14-[2-(3-methylamino-5-phenyl)thieno]tetradecanoate 9g. In accordance with the above general procedure, the residue obtained from a stirred solution of a mixture of compound **1a** (40 mg, 0.179 mmol), $Hg(OAc)_2$ (86 mg, 0.270 mmol), (cyclopentadec-1-enyloxy)trimethylsilane (64 mg, 0.216 mmol) and TBAF (56 mg, 0.214 mmol) and MeOH was chromatographed to give title compound **9g** (25 mg, 32%) as a yellow solid, mp 40–41 °C (from *n*-hexane–EtOAc) (Found: C, 72.6; H, 9.1; N, 3.2; S, 7.5. $C_{26}H_{39}NO_2S$ requires C, 72.7; H, 9.15; N, 3.3; S, 7.5%); ν_{max} (neat)/cm^{-1} 3388, 2912, 1726, 1566, 1494, 1454, 1430, 1386, 1163 and 752; δ_H (300 MHz; $CDCl_3$) 1.25–1.38 (18 H, m, 9 × CH_2), 1.62–1.64 (4 H, m, 2 × CH_2), 2.30 (2 H, t, *J* 7.5, CH_2CO_2), 2.58 [2 H, t, *J* 7.5, $CH_2(CH_2)_{12}$], 2.92 (3 H, s, NCH_3), 3.66 (3 H, s, OCH_3), 6.96 (1 H, s, thienyl), 7.21–7.26 (1 H, m, ArH), 7.30–7.36 (2 H, m, ArH) and 7.53–7.56 (2 H, m, ArH).

2-{2-[2-(3-Methylamino-5-phenyl)thieno]ethyl}benzoic acid 10a. In accordance with the above general procedure, the residue obtained from a stirred solution of a mixture of compound

1a (40 mg, 0.179 mmol), $Hg(OAc)_2$ (86 mg, 0.270 mmol), (3,4-dihydronaphthalen-1-yloxy)trimethylsilane (47 mg, 0.215 mmol) and TBAF (56 mg, 0.214 mmol) and a mixture of THF and water (5 : 1, 10 cm^3) was chromatographed to give title compound **10a** (28 mg, 46%) as a pale yellow solid, mp 173–174 °C (from CH_2Cl_2–Et_2O) (Found: C, 71.25; H, 5.6; N, 4.2; S, 9.5. $C_{20}H_{19}NO_2S$ requires C, 71.2; H, 5.7; N, 4.15; S, 9.5%); ν_{max} (neat)/cm^{-1} 2920, 1576, 1324, 936, 704 and 690; δ_H (300 MHz; $CDCl_3$ + DMSO-d_6) 2.86–2.91 (5 H, m, CH_2 and NCH_3), 3.21 (2 H, t, *J* 7.6, CH_2), 6.95 (1 H, s, thienyl), 7.21–7.30 (5 H, m, ArH), 7.42–7.45 (1 H, m, ArH), 7.53–7.56 (2 H, m, ArH) and 7.98–8.01 (1 H, m, ArH).

Methyl 2-{2-[2-(3-methylamino-5-phenyl)thieno]ethyl}-benzoate 10b. In accordance with the above general procedure, the residue obtained from a stirred solution of a mixture of compound **1a** (40 mg, 0.180 mmol), $Hg(OAc)_2$ (86 mg, 0.270 mmol), (3,4-dihydronaphthalen-1-yloxy)trimethylsilane (47mg, 0.215 mmol) and TBAF (56 mg, 0.214 mmol) and MeOH (2 cm^3) was chromatographed to give title compound **10b** (35 mg, 56%) as a pale yellow liquid (Found: C, 71.9; H, 6.05; N, 4.0; S, 9.1. $C_{21}H_{21}NO_2S$ requires C, 71.8; H, 6.0; N, 4.0; S, 9.1%); ν_{max} (neat)/cm^{-1} 3392, 2944, 1715, 1570, 1501, 1429, 1392, 1253, 1189, 1072 and 755; δ_H (300 MHz; $CDCl_3$) 2.86–2.91 (5 H, m, CH_2 and NCH_3), 3.20 (2 H, t, *J* 7.6, CH_2), 3.91 (3 H, s, OCH_3), 6.69 (1 H, s, thienyl), 7.21–7.30 (5 H, m, ArH), 7.42–7.45 (1 H, m, ArH), 7.54–7.57 (2 H, m, ArH) and 7.91–7.94 (1 H, m, ArH).

Desilylation with TBAF in the presence of phenylmethanethiol

To a mixture of **1a** (40 mg, 0.179 mmol) and $Hg(OAc)_2$ (38 mg, 0.223 mmol) in CH_2Cl_2 (8 cm^3) was added (cyclohexen-1-yloxy)trimethylsilane (40 mg, 0.236 mmol). The mixture was stirred for 5 min at rt, followed by addition of TBAF (62 mg, 0.237 mmol), and the mixture was stirred for an additional 1 h, followed by addition of phenylmethanethiol (28 mg, 0.224 mmol). The mixture was stirred for 30 min and worked up in the usual manner. Chromatography (1 × 20 cm) of the residue with a mixture of EtOAc and *n*-hexane (4 : 1) as eluent gave *S*-benzyl 5-[2-(3-methylamino-5-phenyl)thieno]pentanoate **11** (30 mg, 42%) as a yellow liquid (Found: C, 69.9; H, 6.35; N, 3.6; S, 16.15. $C_{23}H_{25}NOS_2$ requires C, 69.8; H, 6.4; N, 3.5; S, 16.2%); ν_{max} (neat)/cm^{-1} 3392, 2920, 1686, 1570, 1501, 1389 and 755; δ_H (300 MHz; $CDCl_3$) 1.64–1.72 (2 H, m, CH_2), 1.73–1.81 (2 H, m, CH_2), 2.60 (4 H, m, 2 × CH_2), 2.90 (3 H, s, SCH_2, and NH), 4.12 (3 H, s, NCH_3), 6.94 (1 H, s, vinyl), 7.19–7.36 (8 H, m, ArH) and 7.52–7.55 (2 H, m, ArH).

Desilylation with TBAF in the presence of *n*-propylamine

To the mixture obtained by treatment of a mixture of **1a** (50 mg, 0.224 mmol), $Hg(OAc)_2$ (101 mg, 0.317 mmol) and (cyclohexen-1-yloxy)trimethylsilane (45 mg, 0.266 mmol) with TBAF (71 mg, 0.272 mmol) as described above was added *n*-propylamine (59 mg, 0.998 mmol). The mixture was stirred for 24 h and worked up as usual. Chromatography (1.5 × 10 cm) of the residue with a mixture of EtOAc and *n*-hexane (4 : 1) as eluent gave compound **9a** (19 mg, 29%).

Desulfurization of 4a with Raney nickel

According to the documented procedure, a mixture of excess of Raney nickel and **4a** (29 mg, 0.107 mmol) in MeOH (8 cm^3) was stirred for 24 h at rt under hydrogen atmosphere, followed by filtration to remove the solids. The filtrate was washed with 20% aq. $NaHCO_3$, followed by evaporation *in vacuo*. Chromatography (1 × 30 cm) of the residue using a mixture of EtOAc and *n*-hexane (2 : 1) gave 1-methyl-8-(2-phenylethyl)azocin-2-one **14a** (*n* = 4) (11 mg, 0.045 mmol) as a colorless liquid (Found: C, 78.1; H, 9.4; N, 5.7. $C_{16}H_{23}NO$ requires C, 78.3; H, 9.45; N, 5.7%); ν_{max} (neat)/cm^{-1} 3488, 2912, 2864, 1632, 1450, 1392, 1235, 1082, 749 and 698; δ_H (600 MHz; $CDCl_3$) 0.91–0.95 (1 H, m), 1.35–1.37 (1 H, m), 1.57–1.59 (1 H, m), 1.67–1.71 (2 H, m), 1.80–1.88 (3 H, m), 1.96–1.98 (1 H, m), 2.26–2.29 (3 H, m), 2.52–2.56 (1 H, m), 2.70–2.73 (1 H, m), 2.81 (3 H, s, NCH_3), 3.75–3.80 (1 H, m, methine), 7.16–7.17 (2 H, m, ArH), 7.19–7.22 (1 H, m, ArH) and 7.27–7.31 (2 H, m, ArH); δ_C (75 MHz; $CDCl_3$) 22.92, 24.35, 25.95 (NCH_3), 28.42, 31.47 (benzylic C), 33.02, 33.39, 33.83, 52.83 (C-8), 125.16, 127.40, 127.54, 140.07 and 176.00 (C=O); *m*/*z* 245 (M^+, 56%), 202 (7), 154 (18), 148 (77), 140 (100), 132 (19), 126 (72), 91 (74). Continuous elution with the same solvent gave 1-methyl-8-(2-phenylethylidene)-azocin-2-one **13a** (*n* = 4) (6 mg, 0.025 mmol) as a colorless liquid (Found: C, 78.9; H, 8.6; N, 5.75. $C_{16}H_{21}NO$ requires C, 79.0; H, 8.7; N, 5.8%); ν_{max} (neat)/cm^{-1} 3424, 2928, 2864, 1715, 1635, 1440, 1376, 1254, 1235, 1110, 1072 and 1021; δ_H (500 MHz; $CDCl_3$) 1.02–1.06 (1 H, m), 1.61–1.68 (2 H, m), 1.71–1.74 (1 H, m), 1.80–1.85 (1 H, m), 2.03–2.06 (1 H, m), 2.22–2.24 (2 H, m), 2.43–2.49 (2 H, m), 2.55–2.61 (1 H, m), 2.66–2.69 (1 H, m), 2.96 (3 H, s, NCH_3), 5.32–5.35 (1 H, m, vinyl), 7.10–7.15 (3 H, m, ArH) and 7.19–7.24 (2 H, m, ArH); δ_C (75 MHz; $CDCl_3$) 23.97, 24.39, 28.68, 30.69, 32.05, 32.63, 33.77 (C-7), 122.94, 125.15, 127.21, 127.48, 139.04 (C-8) and 139.91 (C-1 of Ph group); *m*/*z* 243 (M^+, 70%), 215 (20), 174 (41), 146 (64), 138 (26), 124 (100). The ^{13}C NMR absorption corresponding to the amide carbonyl carbon was not observed.

General procedure for the completely reductive desulfurization of thienolactams 4a–d

Compound **4** was treated with excess of Raney nickel as described in the preparation of compounds **13a** and **14a**. A mixture of the incompletely reduced products **13** and **14**, obtained by chromatography using a mixture of EtOAc and *n*-hexane (2 : 1), was subsequently treated with PtO_2 (3 wt%) in HOAc (5 cm^3) for an appropriate time at rt. The acids were filtered off and the filtrate was neutralized with 20% aq. $NaHCO_3$, which was extracted with CH_2Cl_2 (3 × 20 cm^3). The extracts were dried over $MgSO_4$. Removal of the solvent *in vacuo*, followed by chromatography (1 × 15 cm) of the residue with a mixture of EtOAc and *n*-hexane (2 : 1), gave lactams **15a**–**d**.

8-(2-Cyclohexylethyl)-1-methylazocin-2-one 15a. In accordance with the above general procedure, the incompletely reduced products obtained from **4a** (28 mg, 0.103 mmol) and excess of Raney nickel were treated with PtO_2 (0.8 mg) in HOAc for 24 h and the mixture was worked up. Chromatography of the residue gave title compound **15a** (15 mg, 58%) as a colorless liquid (Found: C, 76.3; H, 11.6; N, 5.4. $C_{16}H_{29}NO$ requires C, 76.4; H, 11.6; N, 5.6%); ν_{max} (neat)/cm^{-1} 3344, 2912, 2848, 1731, 1629, 1446, 1392, 1258, 1133 and 1075; δ_H (600 MHz; $CDCl_3$) 0.85–0.99 (3 H, m), 1.13–1.25 (8 H, m), 1.33–1.40 (1 H, m), 1.41–1.49 (1 H, m), 1.59–1.80 (8 H, m), 1.85–1.92 (1 H, m), 1.92–1.99 (1 H, m), 2.38–2.45 (1 H, m, $COCH_2$), 2.61–2.68 (1 H, m, $COCH_2$), 2.71 (3 H, s, NCH_3) and 3.79–3.84 (1 H, m, methine); *m*/*z* 251 (M^+, 18%), 208 (12), 166 (47), 154 (43), 140 (100), 112 (15).

12-(2-Cyclohexylethyl)-1-methylazacyclododecan-2-one 15b. In accordance with the above general procedure, the incompletely reduced products obtained from **4b** (55 mg, 0.17 mmol) and excess of Raney nickel were treated with PtO_2 (1 mg) in HOAc for 24 h. The mixture was worked up. Chromatography of the residue gave title compound **15b** (34 mg, 66%) as a colorless liquid (Found: C, 78.1; H, 12.05; N, 4.4. $C_{20}H_{37}NO$ requires C, 78.1; H, 12.1; N, 4.55%); ν_{max} (neat)/cm^{-1} 3344, 2912, 2848, 1750, 1629, 1440 and 1395; δ_H (600 MHz; $CDCl_3$) 0.80–0.91 (4 H, m, conformer B), 1.05–1.12 (4 H, m, conformer A), 1.13–1.52 (22 H, m), 1.53–1.63 (3 H, m), 1.71–

1.90 (2 H, m), 1.97–2.03 (1 H, m, $COCH_2$ of conformer A), 2.12–2.20 (1 H, m, $COCH_2$ of conformer B), 2.61–2.67 (1 H, m, $COCH_2$ of conformer A), 2.72 (3 H, s, NCH_3 of conformer B), 2.79 (3 H, s, NCH_3 of conformer A), 2.79–2.83 (1 H, m, $COCH_2$ of conformer B), 3.74–3.76 (1 H, m, methine of conformer B) and 4.71–4.75 (1 H, m, methine of conformer A).

14-(2-Cyclohexylethyl)-1-methylazacyclotetradecan-2-one 15c. In accordance with the above general procedure, the incompletely reduced products obtained from **4c** (47 mg, 0.13 mmol) and excess of Raney nickel were treated with PtO_2 (1 mg) in HOAc for 24 h. The mixture was worked up. Chromatography of the residue gave title compound **15c** (19 mg, 43%) as a colorless liquid (Found: C, 78.7; H, 12.3; N, 4.1. $C_{22}H_{41}NO$ requires C, 78.7; H, 12.3; N, 4.2%); ν_{max} (neat)/cm^{-1} 3344, 2912, 2848, 1728, 1635, 1446 and 1395; δ_H (600 MHz; $CDCl_3$) 0.80–0.91 (5 H, m), 1.13–1.25 (7 H, m), 1.28–1.49 (19 H, m), 157–1.63 (3 H, m), 1.81–1.89 (1 H, m, conformer B), 2.01–2.08 (1 H, m, conformer A), 2.11–2.17 (1 H, m, $COCH_2$ of conformer A), 2.17–2.22 (1 H, m, $COCH_2$ of conformer B), 2.54–2.61 (1 H, m, $COCH_2$ of conformer A), 2.61–2.66 (1 H, m, $COCH_2$ of conformer B), 2.70 (3 H, s, NCH_3 of conformer A), 2.76 (3 H, s, NCH_3 of conformer B), 3.71–3.77 (1 H, m, methine of conformer A) and 4.66–4.73 (1 H, m, methine of conformer B); *m*/*z* 335 (M^+, 7%), 224 (100), 154 (14).

8-(2-Cyclohexylethyl)azocin-2-one derivative 15d. In accordance with the above general procedure, the incompletely reduced products obtained from **4d** (115 mg, 0.21 mmol) and excess of Raney nickel were treated with PtO_2 (3 mg) in HOAc for 4 days. The mixture was worked up as usual. Chromatography of the residue gave title compound **15d** (90 mg, 81%) as a colorless liquid (Found: C, 82.25; H, 12.01; N, 2.4. $C_{37}H_{65}NO$ requires C, 82.3; H, 12.1; N, 2.6%); ν_{max} (neat)/cm^{-1} 1 3344, 2928, 2240, 1715, 1642, 1443 and 1373; δ_H (600 MHz; $CDCl_3$) 0.65 (3 H, s), 0.73 (3 H, s), 0.85–0.87 (9 H, m), 0.88–0.90 (4 H, m), 0.95–1.03 (3 H, m), 1.08–1.16 (7 H, m), 1.17–1.28 (8 H, m), 1.30–1.39 (6 H, m), 1.41–1.57 (6 H, m), 1.58–1.64 (3 H, m), 1.67–1.73 (2 H, m), 1.79–1.85 (2 H, m), 1.93–2.01 (1 H, m), 2.12–2.17 (1 H, m), 2.19–2.26 (1 H, m), 2.31 (1 H, dd, *J* 13.1, 7.2, $COCH_2$), 2.69 (1 H, dd, *J* 11.9, 9.6, $COCH_2$), 2.95 (3 H, s, NCH_3 of conformer B), 2.96 (3 H, s, NCH_3 of conformer A), 4.90–4.91 (1 H, m, methine of conformer B) and 5.21–5.25 (1 H, m, methane of conformer B).

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